The optimization of Three roller bending process parameter by using the Taguchi method

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ABSTRACT

Roll bending is a continuous forming process, produces higher dimensional accuracy finished products without loss of material. Depending upon to finished product specification different roller Bending machines such as Four roller double pinch bending machines, three roller symmetrical bending machines & three roller asymmetrical bending machines are used. An attempt is made to optimize the process variables of three roller bending parameter such Plate thickness, Desired radius & Yield strength of material using the L9 orthogonal array with three different levels in order to determine the S/N ratio for number of passes which is considered as response of the three roller bending operation. Taguchi analysis performed on the response of roller bending operation in order to determine the most significant process parameter effecting on number of passes. The Regression equation was devolved to perform a confirmatory test

Keyword: - *Three roller bending, optimization, number of passes, taguchi method, regression analysis etc.*

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1. INTRODUCTION

Roll bending or Roll forming is also one of the metals forming processes. In roll bending a long, straight metal strip is passed through a set of rollers to transform it into desired curved cross-sectional profile. Roller bending process can be used to bend sheets or plates to a large range of bend radii, with their smallest one just larger than the diameter of top roller of the bending machine to the largest one as large as shop floor. Cylindrical, conical, elliptical, oval shells are widely used in process industries like power plants, food processing, dairy equipment manufacturing, etc. Various products like cylindrical tanks, drums, boilers, pressure vessels, tunnels, containers, chimneys, towers, structural components are manufactured using roller bending process.[1]. D. E. Hardt et al[2] described real time, close loop shape control for a three roller bending process. Objective of the research was to impart a desired curvature to a work piece at each point along the length of the part. The methodology presented here accomplishes shape control by measuring the loaded shape, loaded moment, and the effective beam rigidity of the material in real time. V. Ramamurti et al[3] studied the fabricated stands of a three roller heavy duty plate bending machine under various loads and parametric study had been performed. Two machines were analyzed for the same. The FEM was used to study the static response of the stands when machine was in operation. The response was calculated for the worst case of loading.

P. S. Thakare et al[4] developed a mathematical model to predict top roller displacement of three roller bending machine during cylindrical operation. Geometrical, operational, and material parameters were considered for the modeling. Methodology of dimensional analysis was used for the same. Percentage variation between experimental results and predicted values were also determined. Shakil A Kagzi, H. K. Raval[5] developed a three dimensional simulation model for three rollers bending process to bend the plates into cylindrical shell using FEM and model was solved in ABAQUS-Explicit solver. Effect of variation in operational and material parameters such as top roller displacement, span of bottom rollers, thickness of plates, and strength coefficient of plate material on bending forces during static and dynamic bending using Taguchi L9 array was investigated.

2. EXPERIMENTAL WORK

2.1. Machine & material: -

Three roller bending machine with Specifications shown in Table 1 is used for the experimentation. In this work, three different grades (Fe 410, Fe 440, and Fe 490) of structural steel are selected as working material. Structural steel is generally used to manufacture boilers, tanks, furnace, etc. Chemical Composition and mechanical properties of the material are shown in Table 2 and Table 3 respectively.

Table 1: Specifications of Three Roller Bending Machines under Study

Sr. No	Parameters	Specifications
1	Diameter of Top Roller (mm)	240
2	Diameter of Bottom Roller (mm)	200
3	Span of Bottom Rollers (mm)	300
4	Motor Used (hp)	7.5
5	Bending Capacity (in thickness)	Up to 10 mm

Table 2: Chemical Composition of Grades of Structural Steel used for Experimentation (IS 2062: 2011)

Materials	Chemical Composition (%)					
	Carbon	Manganese	Sulphur	Phosphorous	Silicon	Carbon Equivalent
Fe410 (E250)	0.23	1.5	0.045	0.045	0.4	0.42
Fe440 (E300)	0.2	1.5	0.045	0.045	0.45	0.4
Fe490 (E350)	0.2	1.5	0.045	0.045	0.45	0.42

Table 3: Mechanical Properties of Grades of Structural Steel used for Experimentation (IS 2062: 2011)

Materials	Mechanical Properties				
	Minimum Tensile Strength (MPa)	Minimum Yield Strength (MPa) (Range of Thickness in mm)			% Elongation at Gauge Length 5.65
		< 20	20 – 40	> 40	
Fe 410 (E250)	410	250	240	230	23
Fe 440 (E300)	440	300	290	280	22
Fe 490 (E350)	490	350	330	320	22

2.2. Design of experiment:

Taguchi method is a statistical tool to accomplish the superior process control through which quality of manufacturing process can be improved substantially. In this research paper work, Taguchi method was implemented on the three roller bending process parameters for structural steel. In the data analysis signal to noise ratios (S/N) are the log function of output which serve function parameter for the prediction of the optimum process outcomes. The Design of experiment was created and generated for nine experimental runs for three factors to find out significant process parameter. The Plate thickness, Desired radius & Yield strength of material considered as important Process parameters and varied in the L9 orthogonal array which is represented in table 4

Table 4. Design Matrix of L-9 Orthogonal Array

Run No.	Input Parameter (Coded Form)		
	Y (Yield strength of material in MPa)	**t (**Plate thickness in mm)	**R (**Desired radius in mm)
1	1	1	1
2	1	2	2
3	1	3	3
4	2	1	2
5	2	2	3
6	2	3	1
7	3	1	3
8	3	2	1
9	3	3	2

In this Taguchi analysis (S/N) ratio has been fixed as a quality indicter to evaluate the influence of change in the design variables on the outcomes of the product. The lower the better ratio was chosen to run the experiment and S/N ratio is calculated using number of passes value for obtaining optimal levels, were calculated by using Eq. no:(1)

$$\eta = -10\, log_{10} \frac{1}{n} \sum_{i=1}^{n} y_i^2 \quad \text{................ Eq. (1)}$$

The predicted S/N ratio for Design of experimental outcomes are shown in Table 5 for number of passes.

Table 5. Signal-to-Noise ratios of Response Parameters

Run No.	Input Parameter (Coded Form)			S/N Ratio Values (db)
	Y	**t**	**R**	**N**
1	1	1	1	-12.0412
2	1	2	2	-12.0412
3	1	3	3	-9.54243
4	2	1	2	-13.9794
5	2	2	3	-12.0412
6	2	3	1	-12.0412
7	3	1	3	-13.9794
8	3	2	1	-12.0412
9	3	3	2	-12.0412

3. RESULTS AND DISCUSSION: -

The Fig. 1 represent arithmetic mean of the S/N ratio for each level of observed factors in concern to number of passes, from the results thickness of Plate was a most influencing parameter to influence number of passes followed by the subsequent process parameter such as the yield strength of material and radius of curvature which also contribute towards the influence response. Optimum process parameter can be identified as controlled factors and can be determined based on S/N ratio which are shown in Tables 6.

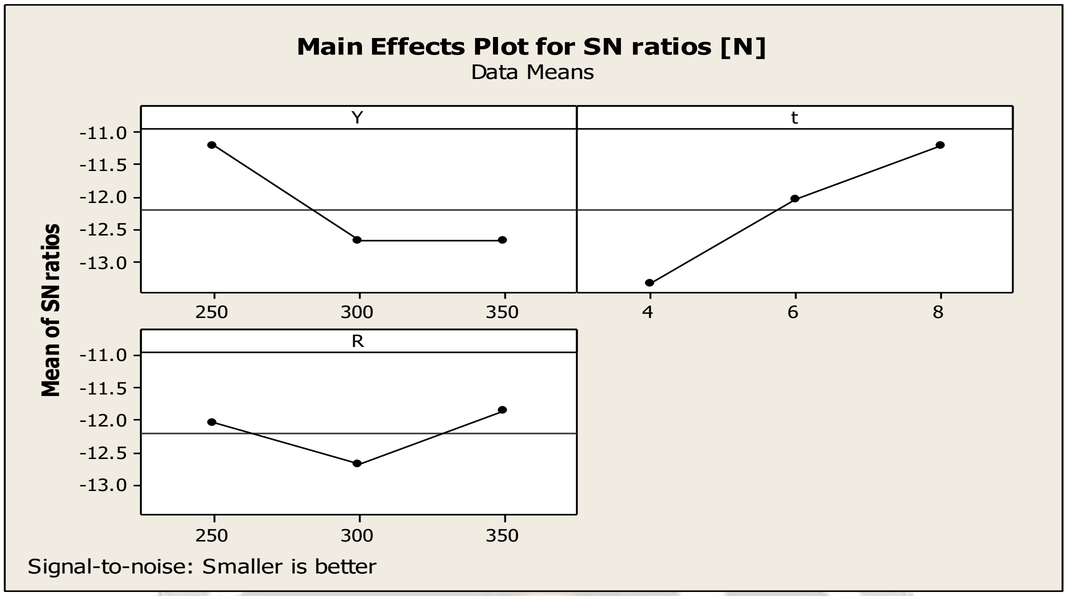

Figure 1 Main Effects Plot for SN ratios [N]

Table: 6 Response Table for Signal to Noise Ratios of Number of Passes, N

Parameters	**Levels**			**Max-Min**	**Rank**
	1	**2**	**3**		
Y	**-11.21**	-12.69	-12.69	1.48	2
t	-13.33	-12.04	**-11.21**	2.13	**1**
R	-12.04	-12.69	**-11.85**	0.83	3
Mean Value of S/N [N] = -12.1943					

The regression analysis has been performed over the process variables to obtain optimized process parameter. The relationship has been established between the process variables of three roller bending operation and measured value of number of passes. The regression equation obtained from the Minitab software are represent below in the Eq. (2)

SNR [N] = - 11.5 - 0.0148 Yield strength of material (Mpa)
+ 0.531 Thickness of Plate (mm) ……………. Eq. (2)
+ 0.00187 Radius of curvature (mm)

The ANOVA analysis performed on the squeeze three roller bending operation variables to decide the effects of controlling factors and interaction based on experimental outcomes of number of passes. The 95% confidence level and 5% significant level was chosen. The F and P value are tabulated in ANOVA results in the Table (7) for the given response. The process parameter having P value less than 0.05 concluded as the significant parameter for the chosen response of number of passes. ANOVA table clearly reveals that the thickness of plate (t) is most significant parameter (p value < 0.05) affecting the number of Passes (N) with the highest percentage contribution of 50.78 % followed by radius of curvature (32.29%) and yield strength of material (8.46%).

Table: 7 Response Table for Analysis of Variance for S/N data [N]

Source	DF	Seq SS	Adj SS	Adj MS	F	P	% Contribution
Y	2	4.3748	4.3748	2.1874	3.82	0.208	32.2954
t	2	6.8792	6.8792	3.4396	6	0.043	50.78325
R	2	1.1461	1.1461	0.573	1	0.5	8.460675
Error	2	1.1461	1.1461	0.573			8.460675
Total	8	13.5462					100

R-Squared = 84.6% R-Squared (adj) = 79.4%

4. CONCLUSION

Taguchi method of optimization has been performed over the input parameters of three roller bending operation such as the Yield strength of material, Thickness of plate and Radius of curvature. The minimum number of passes obtained at the optimum Yield strength of material 250 Mpa, Thickness of plate 8 mm and Radius of curvature 350 mm. The most significant factors of ANOVA analysis indicate that the Thickness of plate influence the number of passes and followed by Yield strength of material and Radius of curvature respectively. The thickness of plate was concluded as a significant parameter which has P value less than 0.05 in Taguchi analysis for number of passes.

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